

Final Report – IN 71374

Our activity in the IN 71374 project in 2007-2008 has been strongly connected to the running NK 62044 project (2006-2009), which has the basic aim to identify experimentally and investigate theoretically the charged hadrons produced with high transverse momentum in ultrarelativistic heavy ion collisions at the CERN LHC (Large Hadronic Collider) accelerator. The Hungarian team is member of the ALICE collaboration, especially we actively participate in the HMPID (High Momentum Particle Identification Detector) subdetector collaboration, in the construction of the planned VHMPID (Very High Momentum Particle Identification Detector) subdetector, and in the theoretical model developments and investigations.

The IN 71374 project offered an extra financial source to strengthen our collaboration with our Italian colleagues on the maintenance of the running HMPID subdetector, to increase the effectivity of the mutual development of the VHMPID subdetector and to accomplish necessary theoretical investigations of high-pT charge hadron production in proton-proton and heavy ion collisions. These activities overlap with our activities in the NK 62044 project, indeed extending those ones.

The accomplished results can be summarized as follows:

1. We have participated in the maintenance of the installed and commissioned HMPID subdetector of the ALICE. The HMPID was ready for data collection in May 2008. During the Summer of 2008 successful cosmic ray tests have been accomplished. In the September of 2008 HMPID was ready for the first proton-proton collisions. Unfortunately, the LHC commissioning have been stalled on 19 September and the operation of the accelerator has been delayed one year. But this fact did not change the readiness and completeness of HMPID for data collection. Our contribution has been published in 2 detector papers.
2. We performed R&D activity in the VHMPID protocollaboration, together with our Italian and CERN colleagues. The main activity of the Budapest group was to develop a trigger unit for VHMPID, based on the application of Thick-GEM (Gas Electron Multiplier) plates, which is a very new technology appearing in micropattern detectors. We constructed the prototype of the trigger unit, made tests in Budapest in our High Energy Physics Detector Laboratory at RMKI. In 2007 May we performed a test measurements of this test unit at the CERN PS beam of 6 GeV/c pions. In 2008 May we have repeated this test at CERN PS with two prototypes, including improved electronics. These tests proved the applicability of our ideas and open the possibility to construct a larger prototype, which is under progress. Our results have been published in 1 paper originated from a talk on an IEEE Micropattern Detector Conference. In parallel the Letter of Intent (LoI) for the construction of the VHMPID detector has been created, which will be submitted to the ALICE Management board in March 2009.

3. During the R&D activity of the VHMPID and the preparation of the LoI new theoretical problems and questions appeared, which have generated new theoretical investigations on high momentum particle production. These investigations have been focused partly in the intermediate momentum region, $3-4 < p_T < 8-10$ GeV/c, where quark coalescence process overwhelms jet fragmentation yield. In parallel we investigated particle production in the $p_T > 10-20$ GeV/c region, especially from strong time-dependent non-Abelian fields, which can be created in ultrarelativistic heavy-ion collisions. The obtained results have been published in 12 theoretical papers (9 have been published in refereed journals).

These results, especially the publications and the tests, indicate the successful accomplishment of our research plan. The research group contained the originally declared members: Levai P, Fodor Z, Barnafoldi GG, Boldizsar L, Futo E, and Molnar L.

The financial support (1 500 eFt/year) has been spent according to the plan, mostly on travelling to conferences (530 eFt/year) and different consumables (130 eFt/year). The miscellaneous costs (680 eFt/year) cover mostly the expenses at CERN to operate the HMPID detector and to support the test beam experiments (beam cost at CERN PS, technician support during set-up, using extra electronical devices to improve the effectivity of the test beam measurements).

In the second part of the Final Report we describe shortly the main properties of the VHMPID detector on the basis of the Letter of Intent, which can be found (its latest versions) on the following WEB-address:

<https://twiki.cern.ch/twiki/bin/view/Sandbox/VHMPIDLoI> .

The main properties of the planned VHMPID detector and the connected tests

The VHMPID detector will consists of two units: the Ring Imaging Cherenkov (RICH) has a volume of $100 \times 100 \times 80$ cm³ filled with C₅F₁₂ and the charged particles will be identified through the radius of the Cherenkov ring connected to the velocity of the hadrons; the trigger unit of a 4-layer structure of ThGEM based detectors in a $100 \times 100 \times 20$ cm³ volume to identify the position of the high- p_T particle and its straight path, which indicates the large momentum. The gas unit is constructed at CERN, the trigger unit is developed in Budapest at the MTA KFKI RMKI. Figure 1 displays the scematic view of the VHMPID detector. The trigger unit serves with a high- p_T trigger ($p_T > 9-10$ GeV/c) and the gas unit separates the charged pions, kaons, protons and antiprotons, which particles have different masses.

Figure 2 illustrates the idea of the trigger process: the charged particle produced in the interaction point (IP) at the center of the ALICE detector, and the magnetic field bends the path of the particle, thus the 4-layer structure is able to determine the incoming angle of the particle. A fast electronic separates the high momentum and the low momentum particles, creating a trigger signal within 6 microsecond.

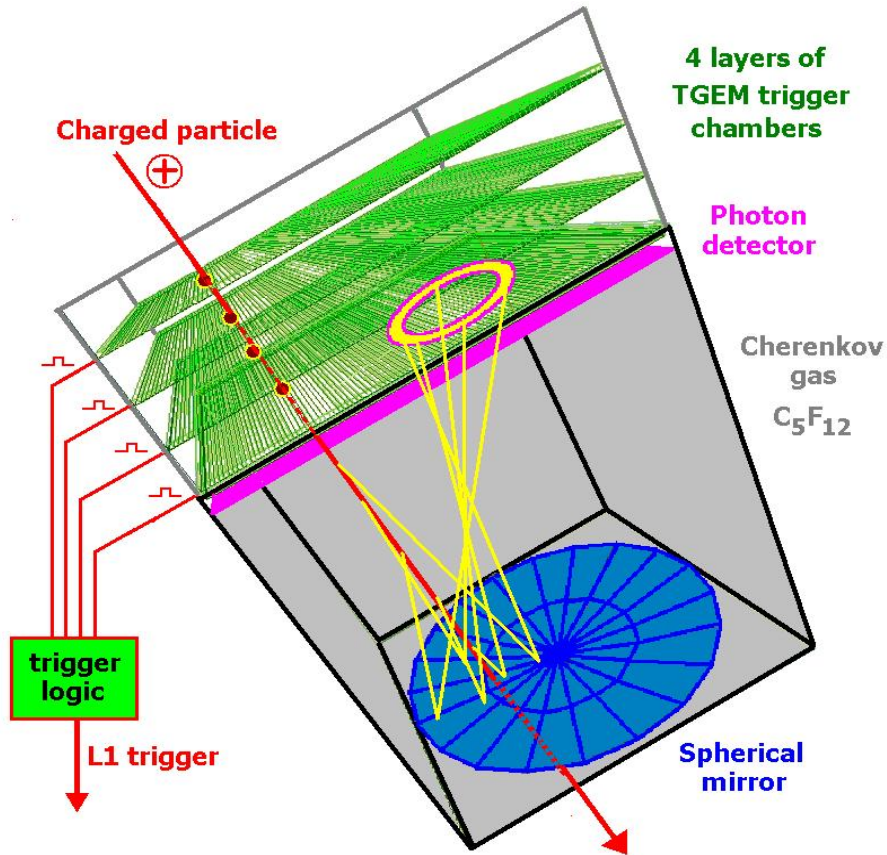


Figure 1: The VHMPID detector with the gas modul and the 4-layer trigger modul located at the front of the detector. The Cherenkov ring at the top of the gas modul is produced by the mirror at the bottom from the Cherenkov radiation.

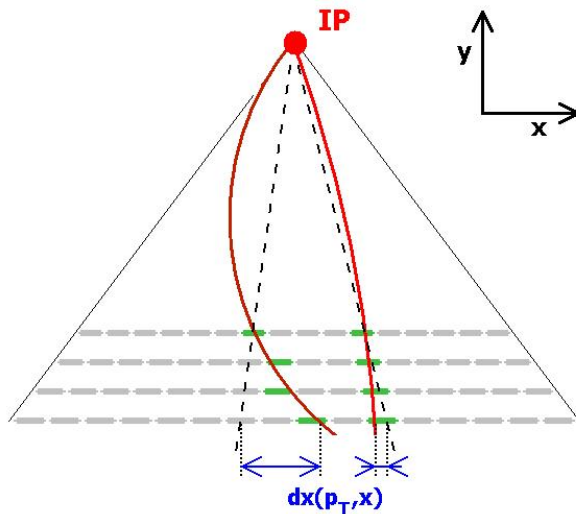


Figure 2: The magnetic field ($B=0.5$ T) of the ALICE detector diverts the charged particles inside the magnet. The radius of the path is large for small momentum and small for large momentum. The 4-layer structure can identify the radius and can work as a threshold trigger. The simulations indicate an optimal threshold of 9-10 GeV/c.

Figure 3 displays the construction of such a trigger layer on a schematic drawing, especially in the case of the prototype, which has been built and tested. Figure 4 shows the existing prototype with size of $10 \times 10 \text{ cm}^2$. The gas volume of the trigger detector is filled with an argon-carbondioxid mixture to shift the sparking limit as high as possible.

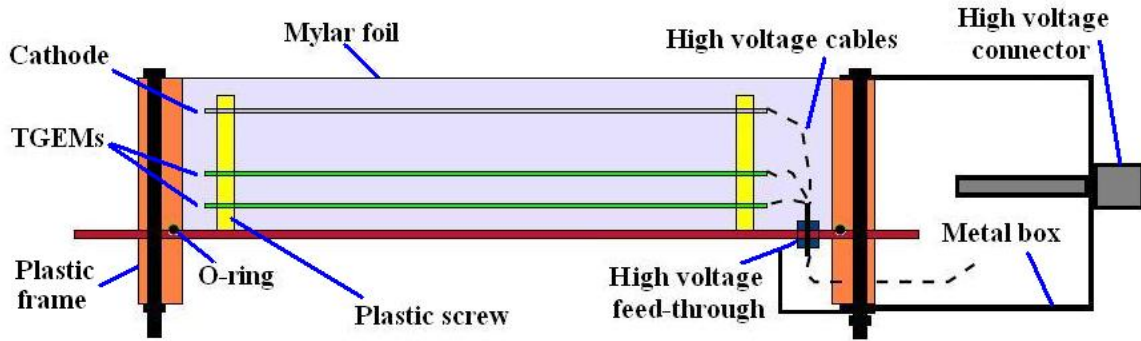


Figure 3: The inner structure of one trigger layer with 2 ThGEMs.

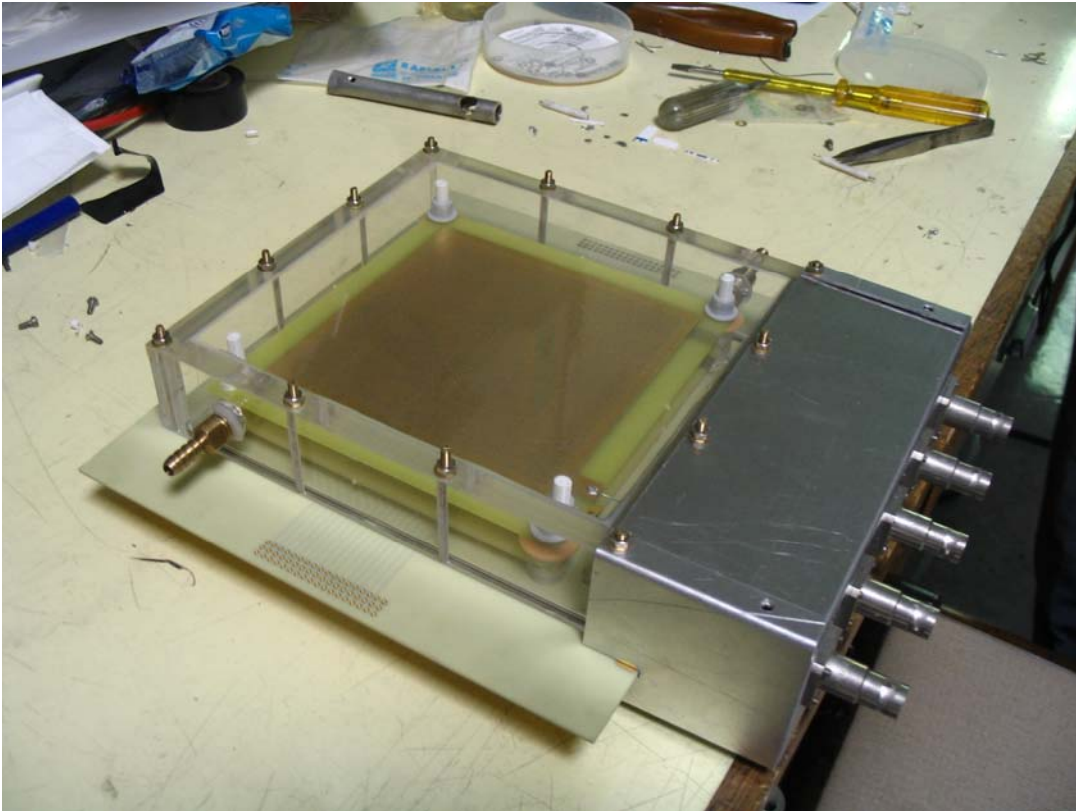


Figure 4: The trigger prototype built at RMKI with 2 ThGEMs layer. Its actual size is $10 \times 10 \text{ cm}^2$.

This trigger prototype has been tested at first on May 2007 at CERN PS in a 6 GeV/c secondary pion beam. We have investigated the sparking levels, the signal-to-noise ratio and the applicability of the original idea of triggering. Figure 5 shows the actual set-up at CERN PS beam hall. The primary signals are collected by the data acquisition system, seen in the figure.



Figure 5: The first test of the trigger prototype on 2007 May in the CERN PS beam hall.

In 2008 we improved our read-out electronics and built a second prototype with better ThGEM plates. This set-up was tested at CERN PS in 2008 May (Figure 6). We have solved the modification of the angle of the incoming pions to analysing different values of angle (thus different momenta). We claimed that the basic properties in the GEANT simulation program (details of secondary particle production, signal-to-noise ratios) are settled in a correct way, which can strongly support the validity of our earlier simulations.



Figure 5: The second test with two trigger prototypes in 2008 May at the CERN PS.

These tests have proved the validity of our basic idea to build a trigger modul, which can serve with a trigger signal within 6 microseconds. We have started the preparation of a $30 \times 30 \text{ cm}^2$ trigger unit, which can be tested in 2009 November at CERN PS.

The gas unit has been constructed at CERN, and we have participated in its testing on 2008 November. The gas modul testing is very complicated, the applied electronics is large and very sophisticated. The only advantage is the applicability of the electronics and data acquisition known already at HMPID. One of the recent activity is to construct a better electronics and test it in a working model. This is planned in 2009.

In case of successful testing and the acceptance of the Letter of Intent by the Management Board of the CERN ALICE experiment, the VHMPID subdetector can be constructed. To increase the small acceptance of one modul (approx 1 m^2), the full size VHMPID will consists of 12 modules, covering 5-8 % of the full acceptance of the TPC. Figure 6 shows the existing PHOS modul at the lower shell of the ALICE detector (middle) and the planned VHMPID modules (12 units). The Collaboration board of ALICE will decide about the construction of the VHMPID in the Spring of 2009.

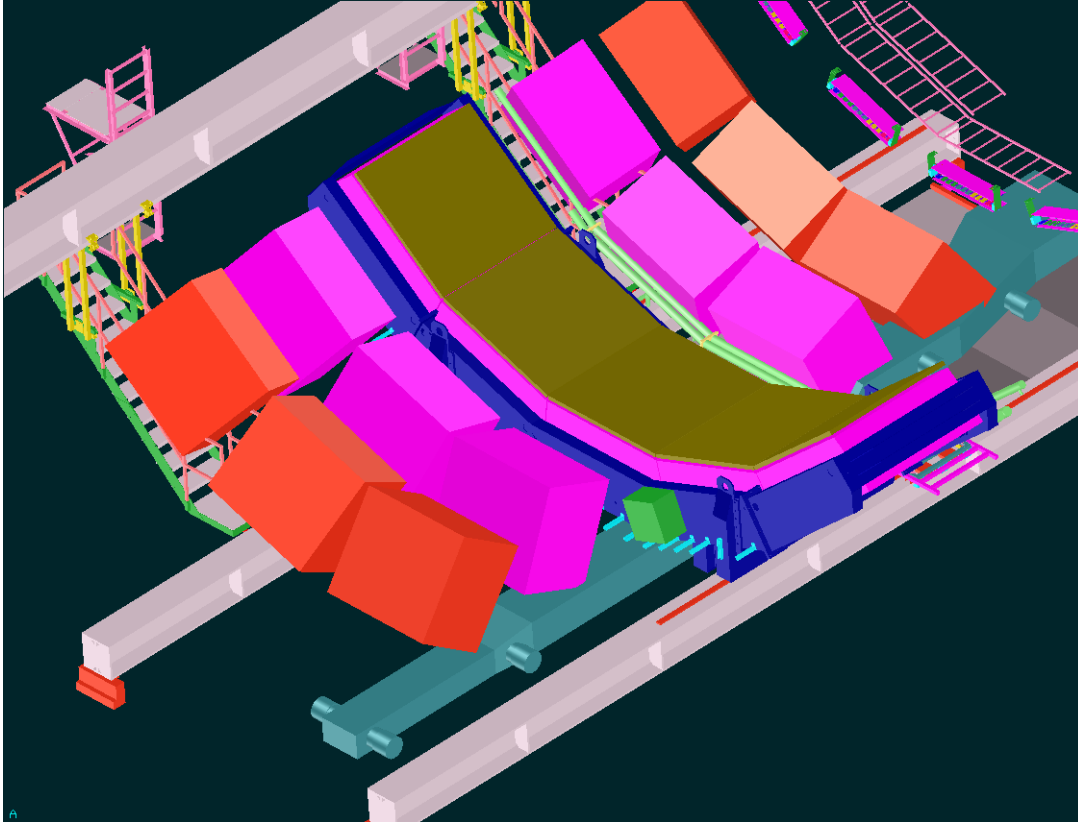


Figure 6: The planned VHMPID detector with 12 modules on the left and right side of the PHOS detector (middle).

Our project has important contribution to the VHMPID related R&D activities. In parallel it was very fruitful to participate in the international collaboration during last 3 years, because to satisfy the international standards we needed to improve the quality and effectivity of our R&D work in Budapest.

We thanks the financial support of the OTKA grant IN71734 to support our activity and our collaboration with other international teams.

Budapest, 27 February 2009.

Peter Levai
Team leader of the ALICE group